How detailed should social networks be for labor market's models ?

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How detailed should social networks be for labor market's models ?

Zach Lewkovicz[1], **Samuel Thiriot**[2] and **Philippe Caillou**[3]

Abstract. Many empirical studies emphasis the role of social networks in job search. The social network implied in this process is known to be characterized by complex properties, including communities, homophily or more or less strong ties. Nevertheless, previous models of the labor markets fail to capture the complexity of social networks, as each specific network requires the development of specific algorithms. In this paper, we rather rely on an independent generic network generator for creating detailed networks describing friendships, colleagues, communities and various degrees of connectivity. We build a simple model of the labor market in which individuals find positions solely through their acquaintances, and update their network when being hired. This original experimental setting facilitates the analysis of various characteristics of networks on the labor market, including various size, more or less friendships, or the impact of communities. Experiments confirm the "strength of weak ties" phenomenon. However, the initial characteristics of the network like communities are shown to be destroyed by the implausible mechanisms described into this simplistic model; this suggests that the impact of plausible networks on models' dynamics may only be studied when the mechanisms of this model are plausible as well - in other words, "a model is only as descriptive as its most implausible components".

1 Introduction

1.1 Empirical evidence on the use of social relationships in labor markets

Field studies on job search highlighted several stylized facts. First, (Stylized fact 1), it appears that searching and finding a job implies the use of social acquaintances to retrieve information [16, 17] (see [10] for a review). As an illustration, Granovetter's studies indicate that about 50 percents of jobs are found through friends, relatives and other social contacts [7]. As done since decades in sociology [23] and economics [11], this social structure is commonly represented using the social network metaphor: each individual is assimilated to a node, with communication links being represented as edges in this network. From an economic viewpoint, the communication of job opportunities through social relationships may lead to incomplete information in the market, thus possibly leading to a market efficiency lower than the optimal one.

Secondly (stylized fact 2), all ties are not used in the same way by job seekers, nor lead to the same information. Since the famous Granovetter's studies on job search [9, 8], it became common to distinguish weak and strong ties; strong ties in a social network reflect frequent interactions between individuals, while weak ties typically lead to less frequent and less personal relationships. Moreover, strong ties are more local, because they are mainly created and maintained because of common workplaces (co-workers), life-places or other activities (near family, friends); typically, the clusters observed in social networks are mainly made of strong ties. Weak ties are more random in the network; they correspond to old friendships born at school or far family. Granovetter observed that despite of long distance and rare interactions, weak ties are more efficient for finding job opportunities than strong ties: strong ties correspond to less diversified people who may communicate easily but receive the very same information, while weak ties link more different people exposed to different types of information. These observations were replicated on different countries and populations (see [19, p.5] and [10] for detailed reviews).

The third stylized fact (stylized fact 3), shared by all empirical studies on social networks [6, 23], underlines the complex nature of these social networks. First, the position of agents on their social environment is far from being random; at the dyadic level, it appears that people tend to bond together when they have close socio-demographic characteristics or interests (homophily), or more generally that the existence of a social tie depends on the properties of individuals (assortativness). The use of social acquaintances to search for jobs often changes with location and demographic characteristics. Living in the same location increase the probability of co-working, as do similar socio-demographic characteristics [2]. Moreover, complex patterns are robustly observed in real networks at the scale of the triad (strong clustering or transitivity rate, intuitively corresponding to the "friends of my friends are also my friends" effect). The recent stream of statistical analysis of large networks [15] also highlighted network-scale properties of real networks, including the frequent presence of biased distribution of degree of connectivity (most people have few ties, while few trust a big number of relationships).

1.2 Previous models of the labor market with information transmission

Models of the labor market progressively took into account the stylized facts described before. First, the use of social networks for conveying information was added to the models[3]; Montgomery [14] highlighted how heterogeneity in the efficiency of job search could arise from structural characteristics. Cahuc and Fontaine [5] showed that these networks lower the efficiency of the market and lead to the existence of several local equilibria instead of a global one.

Some authors described different kinds of links in their networks (multiplex networks) in order to recreate weak and strong ties. No-

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tably, Tassier [20] developed an algorithm that enables to tune the proportion of local vs. random social links across the population. This study enabled the reproduction of the Granovetter's strength of weak ties effect, and proved the importance of the ratio local/random links on market efficiency.

Some recent models also described attributes of agents, that are created according to their position in the network, in order to comply with stylized fact 3. Bramoullé and Saint-Paul [4] describe homophily on salarial status by giving a higher probability for two individuals having the same employment status to be linked together. Tassier [19] used an ethnicity attribute for the agents, and studied the sensitivity of the market to more or less overlapping between communities (see also [10] for a detailed review of existing models). Unsurprisingly, the impact of the social network appears to be strong at different scales: the initial position of agents over the network impacts their probability of finding a job, communities may be more or less efficient depending to their endogenous structure, while all these local phenomena also create different levels of efficiency at the population scale.

In short, both empirical and theoretical studies agree on the impact of local properties of networks on labor markets' efficiency. Models taking into account the complexity of networks remain rare and limited: they only assess the impact of one specific detail (ethnicity, spatialization, etc.) on the market's dynamics. Many other properties of real networks, like the frequent presence of biased distribution of connectivity, remains unexplored. The difficulty to generate "plausible" detailed networks probably constitutes an explanation of these choices.

1.3 Open questions

Despite of the increasing number of models devoted to the study of the labor market, several questions remain open, including:

- *How to generate "rich" networks*, that is networks having several of the properties observed in real networks ? This generation is mandatory for the study of the impact of these properties to the dynamics of the labor market. However, generating such a network constitutes a difficult question in itself, which was not solved for the previous models, thus limiting these studies on networks' impact to only one attribute or three links types. In short, this technical limitation on networks generation forbids the computational study of the impact of these numerous complex properties.
- *How realistic should an initial network be* for models of the labor market in which the network evolves ? Previous works studied either the impact of a static and detailed network on simulations (e.g. [19]), or the evolution of a simple network ([18]). Coupling these dynamics may increase (or lower) the sensitivity of the models to the initial network. Once the sensitivity of such a model is known, the incorporation of social networks into a descriptive model of labor market may become possible.

1.4 Outline

In the next section we will describe the two components of our experimental setting: the use of a generic network generator for constructing the initial networks and a simple model of the labor market. In section 3 we show some results of experiments focused on the efficiency of various link types for finding a job, and on the evolution of networks. As discussed later (4), these experiments suggest that using "rich" initial networks is useless if the dynamics of the model is unrealistic enough for changing its initial structure.

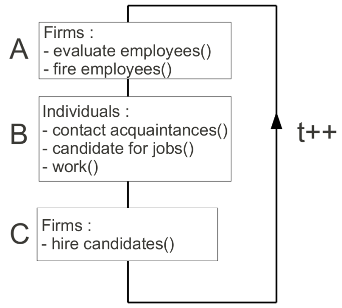

Figure 1. A whole cycle in the simulation

2 Model and Experimental setting

2.1 Model of the labor market

We keep our model as simple as possible in order to catch the most fundamental aspects of the labor market itself. We present here the agents participating in the simulation, its protocol and properties (hypothesis) that we use.

2.1.1 Agents

Two types of agents are used in the model: Individual agents and Firm agents. Firm agents propose jobs and hope to fill them with Individual agents who propose their labor and hope to occupy the jobs.

An **Individual** agent can be in one of these two states: An *Employed* agent is currently occupying a job. *Unemployed* agents do not have a job, but they are looking for one. An Individual agent is described by its gender, state and the acquaintances it has.

A **Firm** agent offers jobs, hires and fires Individual agents. Jobs are represented as objects belonging to Firms. A job can be in either *Filled* (An Individual agent is currently occupying this job) or *Vacant* (the job is not filled and the Firm agent would like to hire an Individual agent to occupy it). A firm agent is described by its size which is the number of jobs (vacant or filled) it possesses.

2.1.2 Protocol

A cycle in the simulation takes place in 3 parts (see Figure 1). First (A), Firms lay off some of their employees with a random probability *p_fire (=10%).*

In the second part (B) Individual agents interact. If they unemployed, they look for a job. In this basic model, individuals may only find jobs using their social acquaintances (as done previously [1]). The Individual agents may contact their friends, colleagues etc. Then they candidate to all the vacancies they encounter.

In the last part of the cycle (C) Firms iterate all their vacancies. If a vacancy got no candidature requests, it stays vacant. When a vacancy has several candidates, the Firm chooses randomly a candidate to be hired under the condition that it will not hire an individual who it just laid off. As soon as an individual is hired, his new colleagues are added to his set of "colleague" acquaintances; however, in order to forbid agents to know the entire population, colleagues are then removed randomly from this list of acquaintances, in order to keep the list of colleagues to at most $max\_colleagues$ (parameter). As a consequence, individuals remember past colleagues from past positions; however, the older the colleague, the higher the probability to break this tie.

2.1.3 Hypothesis

The structure of the simulated labor market and the interactions between the agents follow the hypothesis listed in table 1.

1. The numbers of jobs and Individual agents in the simulated labor market are equal. That means the a situation of zero unemployment is possible.
2. The numbers of jobs and Individual agents are constant throughout the simulation. That means that Firm agents cannot destroy nor create new jobs and the Individual agents do not age nor enter or leave the simulation.
3. Firms are passive in the process of job searching. They do not advertise their vacancies and therefor do not spend time nor money in trying to improve their chances of filling their vacancies.
4. Individual agents in the state of unemployment are constrained to look for a job. They may not stay in unemployment without an active action of job-search (leave to inactivity).
5. Unemployed individuals contact there social networks: Spouse, old colleagues, friends and spouse's colleagues. In order to look for vacancies. All vacancies encountered are listed and a candidature is sent to each one of them.
6. Unemployed individuals candidate to all vacancies they encounter.
7. In order that an agent be able to communicate vacancies to a job-seeker, he has to be employed. In this case he communicates vacancies available in the firm in which he is employed.
8. Job selection (matching) is purely random; this hypothesis simplifies the analysis of the dynamics, as all workers have theoretically equal probabilities to be hired, the only bias being induced by their position on the network (as done in [19]).
9. Worker agents are fired in a pure random way. They stay employed until they are fired. They may not quit the firm.

Table 1. Hypothesis

2.2 Social network

The YANG network generator [21] stands as a generic tool dedicated to the generation of plausible networks for social simulation. Its principle is to accept rich parameters in order to reconstruct plausible networks from rules at the local scale. Resulting networks are multiplex (different kinds of relationships), mixed (directed or undirected links) and attributed (each individual has attributes and is positioned in a plausible social neighborhood). We set the parameters in order to (i) generate a population of agents, which includes both individual and firms, and (ii) to create an initial matching between firms and agents, as well as the numerous social links. Note that all individuals are assumed to be potential workers.

Link types are provided as couples {name, directionality}. In this application, we use here as link types: {{married, undirected},{worksInFirm, directed},{colleagues, undirected},{friends, undirected}}.

The network generator accepts as many *discrete agents' attributes* as desired. We define here the attributes listed in Table 2. Attributes of agents are described in YANG as random variables in a Bayesian network. This formalism enables the description of interdependencies between attributes. Probabilities associated with these variables are defined as follows: agentTypes takes value 'firm' with probability 0.1 and 'individual' with probability 0.9, leading the generator to create one firm per nine individuals. In the same way, gender take

attribute	domain	depends on
agentType	{firm, individual}	{∅}
gender	{notRelevant, male, female}	{agentType}
salarialStatus	{notRelevant, employed, unemployed}	{agentType}
auto_friends_degree	{0..10}	{agentType}
auto_wedding_degree	{0,1}	{agentType}
auto_eco_indegree	{0..20}	{agentType}
auto_eco_outdegree	{0..20}	{salarialStatus}

Table 2. Agents' attributes. Attributes in italic correspond to the degree of connectivity for generation rules.

'male' and 'female' values with probability 0.5 for individuals and value 'notRelevant' for firms. At initialization, 10% of the workers are not tied to firms and will have to find a job[4]. Attributes in italics in Table 2 correspond to the degree of connectivity for various generation rules described below. In practice, the degree for friendship (attribute *auto_friends_degree*) will be set to 5 or 2, depending to the experiments. In and out degree of connectivity for the matching of firms (*auto_eco_indegree* and *auto_eco_outdegree*) respectively describe the number of links getting out of an individual (1 if employed, 0 else) and going in a firm (9 for all firms in the first experiments).

rule name	method	principle
wedding	attributes	create links 'spouses' between males and females for 80% of agents with max degree 1
match	attributes	create links 'worksInFirm' between individuals having 'employed' as salarialStatus and firms
colleagues	transitivity	when an agent A1 'worksInFirm' A2, and another agent A3 'worksInFirm' A2, then create a link 'colleague' A1 and A3
friendsRandom	attributes	create links 'friendship' between individuals in pure random way

Table 3. Generation rules

The last parameters of the generator are the *generation rules*[5], which describe how the links are actually created in the population. YANG accepts two types of generation rules: "attributes rules" refer to generation rules that match two agents depending to their attributes, while "transitivity rules" propose the creation of links at the triadic scale by transitivity. We define the generation rules described in Table 3. The spirit of these rules, which will be applied in this order, is to create wedding links; then, to attribute to each worker a firm; then, to create links between all the colleagues; last, to create friendship links randomly across the population.

The YANG network generator uses all of these parameters for generating random networks of size N. It first creates the whole population, each agent being given a combination of the possible attributes values. This population is stored in an SQL database. Then, the generator applies all the generation rules, by retrieving agents that may be tied together by SQL set operations on the population. The software that implements the generator also provides dynamic visual-

[4] Which will generate initially 10% of unemployment.
[5] Note that attributes rules always implicitly take into account the degree described before as an attribute of the agent. Laso Note that some of these rules are changed in some experiments.

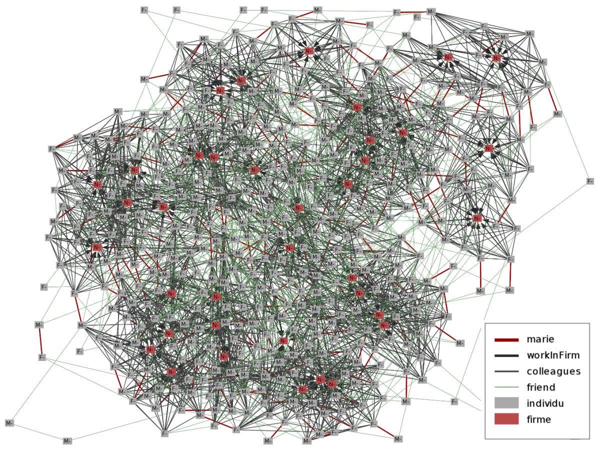

Figure 2. Example of a initial network used as a parameter.

ization of the network generation in order to check their plausibility. More details on this algorithm are provided in [22]. The detailed parameters are provided as supplementary material for reproduction purpose[6]. An example of a resulting network is depicted in Figure 2.

It is important to note that, as this network generator is random, the generated population may be slightly biased; for instance, the actual proportions of agents and firms may be 85/15 instead of the theoretical 90/10. As a consequence, the number of positions and individuals in sometimes not strictly equal in generated networks. To solve this problem, when networks are loaded, open positions are removed randomly if positions are too numerous, or open positions are added if workers are too numerous.

2.3 Implementation

Our model was implemented in Java (1.6) under the platform Repast[7]. In order to get the results we present here we used 1 000 agents : 900 Individuals and 100 Firms. The generation of the simulations took place in 2 stages. First we generated the network which defined the number of agents, their characteristics and the relationships between them. Then we used this network in order to initialize the population of agents that interacts during the execution of the simulation. During this execution we gathered several statistic data which we will present and analyze in the next section.

3 Experiments

At initialization, the state of the population depends on the construction of the model: $\sim 10\%$ of individuals are employed by a firm; the rate of open positions is exactly the same. At each step, each agent has a probability of 10% to be fired (firing rate fixed to 0.1). Agents initialized as unemployed attempt to find one of the available positions in their social neighborhood.

Once unemployed, each agent candidates through his 5 friends (or 2, depending to the experiment), his spouse (if married) and his 5 colleagues (with $max\_colleagues$ set to 5). In practice, the colleagues of the position he last quit are useless, as this firm cannot hire him immediately. Also, candidatures are only allowed at degree 2 (individuals candidate to positions available in the firms of their neighbors). If a position is open in its neighborhood, the individual may be hired by this firm; in such a case, he discovers several new colleagues (and forgets few old ones, such that his total number of colleagues remains under $max\_colleagues$).

As an individual always keeps his initial friends, and remembers some old colleagues, he accumulates a set of acquaintances which is more and more efficient to find positions in new firms. Experiments prove that with this dynamics, he may even "travel" across the networks while he discovers new open positions, new colleagues, and so on.

During the experiments, we measure the unemployment rate, the average number of firms visited by individuals, and the efficiency of each link type for finding a position.

3.1 The incontestable strength of weak ties

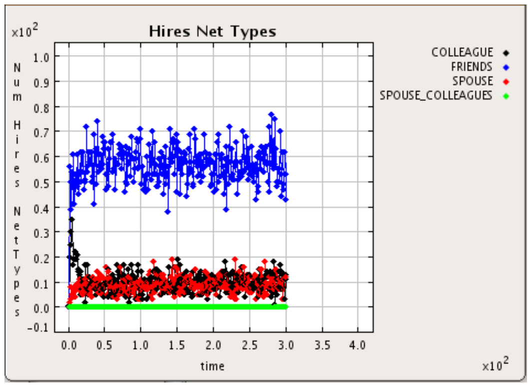

Figure 3. Efficiency of the various link types during a typical run of the model for 5 friends and 5 colleagues.

parameters	Unempl-rate	links efficiency colleagues	friends	spouse	firms count
same size for firms					
5 friends	1.9%	36.9%	54.7%	8.5%	16.57
2 friends	3.0%	55.3%	32.3%	12.3%	13.98
fat-tailed distribution of firms					
5 friends	2.1%	38.1%	53.0%	8.9%	16.62
2 friends	3.2%	54.6%	32.9%	12.4%	13.91

Table 4. Unemployment rate, efficiency of the various link types, and average number of previous positions per agent, for various combinations of parameters.

In this first set of experiments, we explore which links, in this simple model of labor market, enable people to find positions after being fired. The first simulations are run with as many friends as colleagues (5). We observe for each simulation the unemployment rate, the efficiency of each linktype for finding a position, and the total number of firms each individual worked for. As depicted in Figure 3, a typical run starts with a stabilization phase in which agents which were initialized as unemployed in the network search and find jobs. Then, the unemployment rate stabilizes around a certain level (which reflects the market's efficiency) whilst the agents are being fired and

[6] Note for reviewers: sourcecode and parameters will be soon shared on a website like openabm for enabling reproduction.
[7] http://repast.sourceforge.net

search for positions in other firms through their social acquaintances. In order to compare several parameters, we measure the aggregated value for all the indicators after 300 steps for one hundred simulations for each set of parameters (one different network is loaded for each simulation).

Simulations reflect the Granovetter's strength of weak ties: even if individuals have the very same number of friends and colleagues, they actually find most of their positions (55%) through friendship, which is twice as much through colleague links (35%). This effect is explained by the position of these neighbors; while colleagues are mainly aware of the positions available in the former firm in which the individual worked (which can no more hire him), friends are dispersed randomly across the population. Even when we decrease the number of friends to 2 (with 5 colleagues), these links still perform relatively better than colleagues links (Table 4). In this last case however, some unemployed individuals fail to find positions, leading to a higher unemployment rate of 3.0%.

All the firms in these experiments had exactly 9 positions; we now experiment a fat-tailed distribution of firms[8] in order to assess its impact on the market. As reflected by aggregated results (Table 4), the unemployment rate increases slightly: open positions are transmitted by the workers of the firm, which are more numerous for bigger firms. Except this minor change in unemployment rate, the dynamics of the model does not seem to change by this distribution of firms' sizes; notably, the efficiency of each link type remains similar.

3.2 Describing communities: from order to randomness

Evidence from sociological studies demonstrate the strong clustering of populations (see 1.1). As our experimental framework enables to tune the structure of networks easily, we drive several experiments based on networks structured in communities of different sizes. These communities are characterized by a large majority of social links which are endogenous in each community, with only few links creating "shortcuts" between communities. We expect these communities to lower the ability of individuals to find positions opened in other communities, which would lead to a higher unemployment rate and - as a side effect - a lower number of previous workplaces per agent. Inspired by the work of [19], we first created three main areas with only a few links between them. We expected a higher unemployment rate, which was surprisingly not observed in the experiments. As a consequence, we designed a highly clustered network in order to study this phenomenon.

In this experiment, we add a "community" attribute to agents (both firms and individuals). This attribute takes values between 1 and 100 with equal probability (each community has the same size). Endogeneity is strong in this network: friendships only occur in the same community, as do spouse links. Positions are initially filled by individuals belonging to the same community or to close neighbors. For instance, firms in position 50 only hire individuals from communities 49, 50 and 51. As a consequence, initial colleague links are only created at degree three in these communities. The resulting network constitutes a kind of one-dimensional lattice of diameter 24, as depicted in Figure 4. This network is obviously unrealistic and is only used for understanding why communities appear to have such a low impact on the models' dynamics.

In such a highly clustered and large diameter network, we would expect a lower unemployment rate; even if the lowest possible unemployment rate is reached, it should take numerous steps before agents "move" from one part of this large network to another. One more time, experiments contradict this intuition; the unemployment rate is close to the ones obtained in previous experiments. Individuals also explore the same number of firms ($\sim$14.4 in average), despite of the absence of shortcuts in the initial network.

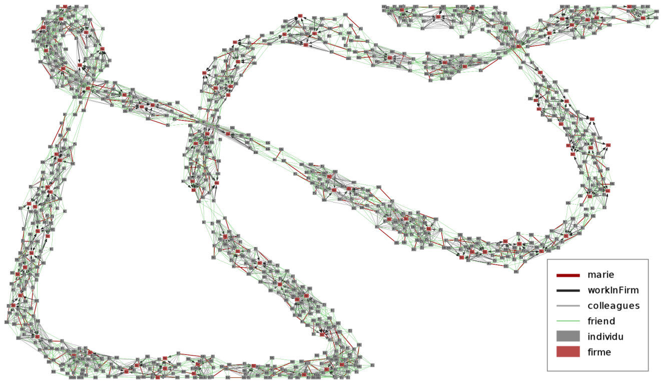

Figure 4. Example of network with one hundred communities.

3.2.1 *Unrealistic dynamics passes over realistic initial networks*

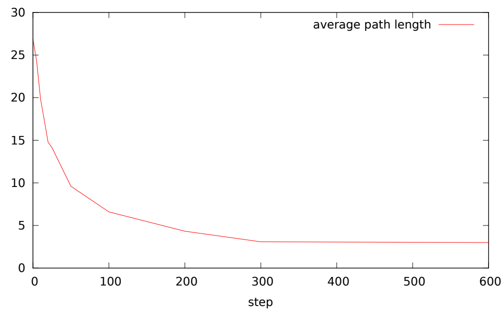

Figure 5. Evolution of network size during steps

An analysis of the social network at different steps reveals how quickly it shrinks (Figure 5). After 300 steps, the average path length in this network is as low as 3.18. Agents changing positions appear to create shortcuts quite rapidly. This leading to a small-world effect already measured in previous experiments [18]. This (possibly) unrealistic drop in network diameter is probably explained by several unrealistic processes in the model:

- There is *no cost for changing community* for agents as would be expected in reality (time, psychological cost, relocation cost) nor costs for repeated change of community (or area).
- Only colleague links are partly changed when individuals are hired; friendship links remain stable and conserve the very same communication power (same efficiency for finding information). In real settings, a higher distance would change these friendship

[8] 50% of the firms have 5 positions, 30% 10 positions, 10% 15 positions, 5% 20 positions and 5% 30 positions.

links, which were first created in the same community, into weaker ties.

This observation may be thought to be an interesting analogy of job markets in which workers are highly mobile and positions are mainly discovered through social acquaintances. Typically, this could be the case of research positions, with post-docs moving from laboratory to laboratory, thus improving not only their own efficiency of finding positions, but also enabling their friends to discover positions in their old laboratories.

Beyond the case of labor markets, this phenomenon underlines an interesting methodological point for agent-based simulation: *the plausibility of a model is as strong as the weaker plausibility of its components*. Providing networks with many details - even if plausible or real - is useless if the dynamics that change this network later is unrealistic. In our example, we increased the plausibility of the initial network, but we did not describe a plausible hiring process; we should haven taken into account both the relocation cost (changing community) and the lower strength of old friendship links.

4 Discussion

In this paper, we set up a framework for exploring the impact of a detailed networks on the dynamics of a simple labor market model. We used the YANG standalone network generator for generating networks having diversified properties such as various link types, degrees of connectivity, firm sizes or the presence of communities. This initial network evolves as individuals discover colleagues when they are hired in new firms. In this simplistic model, interpersonal communication is the only way to discover job positions.

We first studied the *efficiency of the various link-types* used in the model. These preliminary studies confirm the "strength of weak ties" famous phenomenon: as they are created in a random way across the population, friendship links enable individuals to discover open positions in others firms, while colleague links remain focused on the last firms visited by the individual. We have to moderate this observation by the fact that these links were not exactly described as "weak": weak links suppose a small probability to interact, and including such a lower probability would probably reduce their efficiency. Nevertheless, given these observations, using a network generator that enables the description of different link types, appears to be mandatory to build plausible models of labor markets.

We used the versatility of our experimental setting for creating *clustered networks* in which agents' attributes determined their belonging to groups. Surprisingly, the creation of networks, segregated into weakly interconnected communities, did not lead to strong shift in unemployment rate. Indeed, the parameters led to frequent changes in the network (firing rate at 10%). Moreover, the evolution of the network, instead of the initial construction of the network, did not take into account the attributes of agents; as a consequence, this dynamics quickly "changed" the initial structure, making the initial characteristics of the network secondary regarding this evolution. This last observation may be generalized beyond the limited scope of labor markets: in this kind of model in which the network is dynamically changing during the simulation, *the use of a "more descriptive" network is useless if this evolution is based on implausible behaviors.*

Given this first analysis of the evolution of a "rich" initial network into an agent-based model of the labor market, we plan to limit the destruction of the initial network by associating probabilities of interaction to link types. Once the deformation of the network will be limited, further inquires will be driven on the impact of various initial structures to the models' dynamics.

Then we would like to couple these social networks with more descriptive models of labor markets (like [12, 13]) in order to study their impact on the labor market's outcomes studied.

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